From: "Thomas, Hattie" </O=EXCHANGELABS/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=B1EBAFC79FA94F308D9F6EBB0424E75A-THOMAS, HATTIE>

To: Brooks
"Karl; Hague"
Mark

CC:

Date: 2/14/2014 3:53:03 PM

Subject: FW: PRESS INQUIRY *** URGENT *** FW: Evaluation of radiationrisk from Bridgeton landfill fire

Attachments: SSE Evaluation 1-14-14.pdf

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FYI – first of two emails. - HLT

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**From:** Whitley, Christopher
**Sent:** Friday, February 14, 2014 2:42 PM
**To:** Hammerschmidt, Ron; Tapia, Cecilia; Thomas, Hattie
**Subject:** PRESS INQUIRY *** URGENT *** FW: Evaluation of radiation risk from Bridgeton landfill fire
**Importance:** High

FYI. I have not yet spoken with her, nor have I replied to her email.

How do you advise I respond?

---

**From:** Lacapra, Veronique C. [mailto:lacaprav@umsl.edu]
**Sent:** Friday, February 14, 2014 2:27 PM
**To:** Whitley, Christopher
**Subject:** Re: Evaluation of radiation risk from Bridgeton landfill fire
**Importance:** High

Hi Chris,

Would someone from the EPA be available to comment on this today?

Thanks,

Veronique
314-516-7480

Véronique C. LaCapra, Ph.D.
Science, Environment and Health Reporter
St. Louis Public Radio | 90.7 KWMU & The Beacon

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# Evaluation of Possible Impacts of a Potential Subsurface Smoldering Event on the Record of Decision – Selected Remedy for Operable Unit-1 at the West Lake Landfill

**Prepared for**

The United States Environmental Protection Agency Region VII

**Prepared on behalf of**

The West Lake Landfill OU-1 Respondents

**Prepared by**

Engineering Management Support, Inc.
7220 West Jefferson Avenue, Suite 406
Lakewood, Colorado  80235

January 14, 2014

# EXECUTIVE SUMMARY

In a July 3, 2013 letter, the United States Environmental Protection Agency (EPA) asked the West Lake Landfill Operable Unit 1 (OU-1) Respondents to expand the risk analysis section of the December, 2011 Supplemental Feasibility Study (SFS) to consider risks from a subsurface smoldering event (SSE), either originating in the Bridgeton Landfill portion of Operable Unit 2 (OU-2), or developing within West Lake Areas 1 or 2 (OU-1). EPA requested a qualitative assessment that takes into account how the remedy design for OU-1 would address the presence of an SSE, should one occur. EPA also indicated that the evaluation should discuss potentially applicable or relevant and appropriate requirements (ARARs) associated with a possible SSE. This SSE Evaluation Report presents that expanded risk analysis, potential ARARs identification, and the EPA Record of Decision (ROD) remedy design evaluation.

After considering the conditions and processes known to be associated with subsurface heating events at landfills and the remedy selected by EPA in the 2008 ROD, this Report concludes that:

- The radiologically-impacted material (RIM) disposed of in West Lake Areas 1 and 2 will not become more or less radioactive in the presence of heat. Likewise, the RIM is not explosive and will not become explosive in the presence of heat.

- An SSE does not create conditions that could carry RIM particles or dust off the site. The heat of an SSE is not high enough to ignite non-RIM wastes or chemical compounds or to cause them to explode.

- An SSE may allow radon gas to more easily rise through the ground and reach the surface of the landfill than would otherwise occur, because heat will would reduce the amount of moisture in the buried solid waste (trash) thereby increasing the amount of air between the soil particles and thus limiting the ability of the buried solid waste to retain radon below ground. Any radon gas that does make it to the surface would dissipate quickly in open air. This potential increase in the rate of release of radon gas at the surface of the landfill would be limited to the area of the SSE and would stop when the SSE ends.

- An SSE in West Lake Area 1 or 2 would create no long-term additional risks to people or the environment.

- Any short-term risks would be associated with the temporary increase in radon gas coming from the surface of the landfill if no cap is installed on the landfill, or if the cap called for by the 2008 ROD was not properly maintained.

- These short-term risks can be addressed by designing, building, and maintaining the landfill cap called for by the 2008 ROD, and by maintaining the land use restrictions already in place on the entire West Lake property, which prevent certain site uses.

- There are no additional ARARs associated with an SSE.

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List of Acronyms

| | |
|---|---|
| AIT | Auto Ignition Temperature |
| ARAR | Applicable or Relevant and Appropriate Requirements |
| BOD | Biological Oxygen Demand |
| C&DD | Construction and Demolition Debris |
| C | Centigrade |
| CERCLA | Comprehensive Environmental Response Compensation and Liability Act |
| CO | Carbon monoxide |
| cm/sec | centimeters per second |
| EMSI | Engineering Management Support, Inc. |
| EPA | United States Environmental Protection Agency |
| F | Fahrenheit |
| FEMA | Federal Emergency Management Agency |
| FML | Flexible Membrane Liner |
| GCCS | Gas Collection and Control System |
| MCL | Maximum Contaminant Level |
| MDNR | Missouri Department of Natural Resources |
| MSW | Municipal Solid Waste |
| NRC | Nuclear Regulatory Commission |
| OSTRI | Office of Superfund Technology Research and Innovation |
| OU | Operable Unit |
| RIM | Radiologically Impacted Material |
| ROD | Record of Decision |
| SFS | Supplemental Feasibility Study |
| SSE | Subsurface Smoldering Event |
| UMTRCA | Uranium Mill Tailings Radiation Control Act |
| USACE | United States Army Corps of Engineers |
| USDOI | United States Department of the Interior |

# 1. INTRODUCTION

In a July 3, 2013 letter, the United States Environmental Protection Agency (EPA) requested that the West Lake Landfill Operable Unit-1 (OU-1) Respondents expand the risk analysis section of the Supplemental Feasibility Study (SFS) (EMSI, 2011) to include risks associated with a subsurface smoldering event (SSE) reaching OU-1 from the Bridgeton Landfill portion of OU-2, or a new SSE originating within OU-1 (EPA, 2013). EPA requested a qualitative assessment that would consider how the remedy design would address the presence of an SSE, should one occur. EPA also indicated that the evaluation should include a discussion of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations associated with a possible SSE. Engineering Management Support, Inc. (EMSI), on behalf of the OU-1 Respondents, prepared a Work Plan (EMSI, 2013) for this evaluation that was approved by EPA on July 30, 2013.

The West Lake Landfill is a 200 acre, closed solid waste disposal facility that accepted wastes for on-site landfilling from the 1940's or 1950's through 2004. Operable Unit-1 (OU-1) addresses two disposal areas (Areas 1 and 2) where radionuclides are mixed within landfilled soil and solid waste materials, plus an adjacent area (the Buffer Zone/Crossroad Property) where erosion from Area 2 deposited radiologically-impacted materials (RIM). Operable Unit-2 (OU-2) consists of the remainder of the site including areas never used for landfilling, several inactive fill areas containing sanitary waste or demolition debris which were closed prior to state regulation, and a permitted sanitary landfill currently undergoing closure under the State of Missouri's solid waste regulatory program.

The site was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the late 1940s or early 1950s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, 8,700 tons of leached barium sulfate residues, (a remnant from the Manhattan Engineer District/Atomic Energy Commission project) were reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, Missouri, transported to the West Lake Landfill, and used as daily or intermediate cover material. Prior investigations have determined that these radiologically-impacted materials (RIM) were disposed in portions of two separate disposal areas at the site that have subsequently been identified as Radiological Area 1 and Radiological Area 2, or simply Area 1 and Area 2 (Figure 1). As a result of the original use of the radiologically-impacted soil as daily and intermediate landfill cover material and the natural decomposition and consolidation of the refuse which had been covered by the radiologically-impacted soil, the RIM is intermixed with and interspersed within the overall matrix of landfilled refuse, debris and fill materials, and unimpacted soil and quarry spoils in Area 1 and Area 2. In some portions of Areas 1 and 2, RIM is present at the surface; however, the majority of the radiological occurrences are located in the subsurface beneath these two areas.

Landfill activities conducted after 1974 within the quarry areas (part of what is classified as the West Lake OU-2) were subject to permits obtained from the Missouri Department of Natural Resources (MDNR). In 1974 landfilling began in the portion of the site described as the North

Quarry Pit (Figure 1). Landfilling continued in this area until 1985, when the landfill underwent expansion to the southwest into the area described as the South Quarry Pit (Herst & Associates, 2005). Together, the North and South Quarry pit landfills make up the permitted Bridgeton Sanitary Landfill. In December 2004, the Bridgeton Sanitary Landfill stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce the potential for birds to interfere with airport operations. The Bridgeton Sanitary Landfill is inactive and closure activities are proceeding under MDNR supervision.

In December 2010, Bridgeton Landfill detected changes in the landfill gas extraction system; specifically, elevated temperatures and elevated carbon monoxide levels (Bridgeton Landfill, LLC, 2013a). Further investigation indicated that the South Quarry Pit landfill was experiencing an exothermic subsurface smoldering reaction or event – an "SSE" (Bridgeton Landfill, LLC, 2013a). As a consequence of the SSE, the South Quarry Pit Landfill has experienced an increase in fugitive emissions and odors, elevated waste temperatures, and accelerated decomposition of the landfilled solid waste (Bridgeton Landfill, LLC, 2013a). The property owner has performed various evaluations and mitigation activities relative to this event (Bridgeton Landfill, LLC, 2013a, 2013b and 2013 c; MDNR, 2013; and Thalhamer, 2013).

This report provides an evaluation of the potential impacts if an SSE were to occur within Areas 1 or 2 at the West Lake Landfill, both before and after construction is complete for the remedy selected by EPA in the Record of Decision (ROD) (EPA, 2008). More specifically:

- Section 2 of this report presents a general overview of the conditions and processes associated with subsurface heating events at landfills.

- Section 3 summarizes the engineering components of the ROD-selected remedy.

- Section 4 presents an evaluation of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations relative to an SSE in West Lake Areas 1 or 2.

- Section 5 presents an evaluation of the possible impacts relative to potential release and/or migration of radionuclides from the RIM if an SSE were to occur in West Lake Areas 1 or 2.

- Section 6 presents an evaluation of potential impacts on the effectiveness and performance of the ROD-selected remedy if an SSE were to occur in West Lake Areas 1 or 2 post-construction. This section also describes how the design of the ROD-selected remedy would address the presence of an SSE. In accordance with EPA's letter, a qualitative evaluation of the potential impacts of an SSE has been performed based on published literature combined with an understanding of the site conditions, the ROD-selected remedy, and basic scientific principles and processes.

- Section 7 provides a summary and conclusions regarding the evaluations of the potential impacts relative to the occurrence of an SSE in West Lake OU-1 and the impacts of an SSE on the ROD-selected remedy.

- Finally, Section 8 lists the reference documents considered in these evaluations.

## 2. SUBSURFACE HEATING EVENTS

In accordance with EPA's letter and the Work Plan, this section outlines a review of published scientific and regulatory agency literature on subsurface heating events in general. EMSI took a comprehensive approach to the review, recognizing that the scientific literature in this area is in development, and that some articles cited do not apply to the specific conditions at the Bridgeton Landfill portion of OU-2.

### 2.1 Combustion and Pyrolysis (smoldering)

Subsurface heating events are described by many terms, such as subsurface fire, smoldering fire, slow pyrolysis, glowing combustion, subsurface oxidation, and reaction (Ohio EPA, 2011). For purposes of this evaluation, a subsurface heating event will be considered to include any and all of the above listed events.

Combustion or fire is a process involving rapid oxidation of material at elevated temperatures accompanied by the evolution of heated gaseous products of combustion, and the emission of visible and invisible radiation (e.g., heat and/or light) (Biffa et al., 2008). Four elements are necessary for a fire to occur, including fuel or combustible material, sufficient heat to raise the material to its ignition temperature, oxygen to sustain combustion, and an exothermic chemical chain reaction (Biffa, et al., 2008, and Fire Safety Advice Centre, 2011). Combustion is described as a self-sustained, exothermic reaction between fuel and oxidizer, while ignition can be defined as a rapid transition process by which an exothermic reaction and self-supported combustion is initiated (Moqbel et al., 2010). Combustion can occur in two modes, the flaming mode or the non-flaming mode (Biffa, et al., 2008). In the flaming mode, solid and liquid fuels are vaporized, and it is this volatile vapor from the solid or liquid fuels that is visually observed as actually burning in the flaming mode (Biffa et al., 2008). The non-flaming mode involves smoldering or glowing embers. Smoldering is the slow, low-temperature, flameless form of combustion sustained by the heat produced when oxygen directly attacks the surface of a condensed-phase fuel (Rein, 2009). The fundamental difference between smoldering and flaming is that in the former, the oxidation reaction and the heat release occur on the solid surface of the fuel or porous matrix, and in the latter, these occur in the gas phase surrounding the fuel (Rein, 2009).

Although sometimes referred to as landfill fires, subsurface heating events at landfills are not fires in the normal sense of that word, because there are no flames associated with a subsurface thermal event. Deep-seated landfill fires do not 'burn;" instead, these fires are a form of combustion known as pyrolysis, under which the thermal reaction takes place in an oxygen-starved environment and the combusting material is consumed very slowly and at relatively low temperatures (Foss-Smith, 2013). Most subsurface "fires" are thought to exist at the smoldering stage of combustion (Biffa, et al., 2008) and generate heat in the absence of gaseous flames (Dehaan and Icove, 2011). Biffa et al. (2008) define a subsurface fire as the sustained pyrolysis and rapid oxidation of carbon based material at elevated temperatures accompanied by the evolution of heated gaseous products of combustion and the emission of visible and invisible radiation (light and/or heat).

Regarding the existing SSE in the Bridgeton South Quarry Landfill, MDNR states that a reaction associated with an SSE event occurs slowly without a visible flame or quantities of smoke and may be deep within the landfill (MDNR, 2013). MDNR further states that normally, an actual flame will not be observed, and the only time this type of event results in a visible flame or smoke is when the subsurface event is excavated and exposed to the atmosphere.

## 2.2 Causes of an SSE

A subsurface heating event may occur at any solid waste or construction and demolition debris (C&DD) landfill (Ohio EPA, 2011). Examples of some of the causes of subsurface heating events include (Ohio EPA, 2011):

- Aerobic microbiological decomposition of waste (this cause is often associated with an operational failure such as poor cover or the over-application of vacuum on a gas extraction well);

- Chemical reaction (e.g. oxidation) in the waste material. Examples are:
  - Spontaneous combustion, which can occur in such common household wastes as oily rags, paints, solvents, batteries, and pool chemicals.
  - Exothermic reaction when water is combined with certain wastes, such as aluminum production waste, municipal solid waste, ash, lime, iron waste, steel mill waste, and other metal wastes.
  - Oxidation of cellulose and plastics to form peroxides which have a low ignition temperature.

- "Hot loads," such as cooking charcoals, ashes, or smoking materials that are buried but not extinguished.

The most common cause of an SSE is an increase in the oxygen content of the landfill, which increases aerobic (oxygen-based) bacterial activity and raises temperatures (FEMA, 2002). Improper operation of a landfill gas extraction system can include under-pulling or over-pulling. Under-pulling can result in excess emissions of landfill gas to the atmosphere and gas migration (LandTec, 2005a). Over-pulling of a landfill gas extraction system can result in intrusion of atmospheric air (oxygen) into the landfill which disrupts the anaerobic (low- or no-oxygen) decomposition and increases aerobic degradation resulting in increased heat generation and potentially resulting in an SSE (LandTec, 2005a and 2005b and USACE, 2013).

The primary cause of an SSE is spontaneous combustion (Moqbel et al., 2010). Spontaneous combustion is defined as combustion of material in the absence of an externally applied spark or flame (Moqbel et al., 2010). Landfills are complex systems where various interrelated biological and chemical reactions result in waste degradation (Moqbel et al., 2010). An increase in solid waste ambient temperature causes an increase in the oxidation rate and concomitant heat generation (Moqbel et al., 2010). The presence of heat, oxygen and fuel (i.e. solid waste) in the landfill produces the necessary elements of a fire (Moqbel et al., 2010). If this heat is not dissipated, the temperature continues to rise until it reaches the auto-ignition temperature (AIT) of the solid waste, causing a fire (Moqbel et al., 2010).

Methane often has been suspected to initiate spontaneous subsurface fires in a landfill (Moqbel et al., 2010). However, a combustible mixture of methane and oxygen requires a very high temperature to ignite (>500 °C / 900 °F) (Moqbel et al., 2010). Studies conducted by Moqbel et al., (2010) showed that spontaneous fires are initiated by solid materials with lower ignition points. FEMA (2002) reports that municipal solid wastes produced in the United States in 1999 (prior to recycling) consisted of 38% paper materials. Although testing conducted by Moqbel et al., (2010) indicated that the auto-ignition temperature of paper and cardboard was in excess of 300 °C / 572 °F, excess heat generation from exothermic reactions (self-heating) occurs in paper at temperatures slightly below 100 °C / 212 °F; however, these values reflect conditions for dry materials and were greatly affected by the presence and nature of moisture (e.g., water vs. leachate) within the paper. These same studies concluded that the presence of moisture in solid wastes can generally promote self-heating by lowering the solid waste permeability, thereby decreasing heat dissipation, and by increasing the absorption of energy in the solid waste as the liquid evaporates (Moqbel et al., 2010). These studies also concluded that heat generated from chemical oxidation plays a major role in the spontaneous combustion of solid waste (Moqbel et al., 2010).

## 2.3 Indications of an SSE

The following are events or features that could indicate the presence of an SSE in a landfill (CalRecycle, 2013, De Havilland, undated, FEMA, 2002, Ohio EPA, 2011):

- Substantial settlement over a short period of time;
- Smoke, steam or smoldering odor emanating from the gas extraction system or landfill;
- Elevated levels of carbon monoxide (CO);
- Combustion residue in gas extraction wells or headers;
- Occurrences of odors, in particular new odors, odors that smell “hot” or “burning,” or odors of volatile fatty acids or sulfur compounds such as mercaptans;

- Increase in gas temperature in the extraction system;
- Excess temperatures in the landfill mass;
- Changes in landfill gas quality; such as a rapid or localized reduction in methane content or an increase in the ratio of carbon dioxide to methane concentrations indicating the inhibition of biological activity, or an increase in oxygen, nitrogen or balance gas concentrations reflecting over-pulling in the landfill gas extraction systems;
- Excessive liquid (leachate or condensate) generation that cannot be attributed to seasonal variability or operation/construction activities;
- A change in leachate quality; and/or
- Stressed vegetation cover or patchy snow melt.

It is important to note that while this is not an exclusive list, not all of these conditions may be present at a landfill that is undergoing an SSE, and some of these conditions can be caused by factors other than an SSE. The simultaneous occurrence of many of the above factors at a particular landfill is a strong indication of an SSE.

In the case of the Bridgeton South Quarry Landfill, the primary manifestations of an SSE include the following (Bridgeton Landfill, LLC, 2013a):

- Curtailment of methane production in portions of the waste mass where temperature is elevated above 160° F / 71 ° C (which exceed conditions generally considered favorable for the bacteria responsible for methanogenesis);
- Elevated temperatures in the landfill mass which require special construction materials for gas and liquid handling features;
- Production of hydrogen, carbon dioxide, volatile organics, and carbon monoxide, some of which migrate outward and away from the reacting waste materials;
- Creation of odorous emissions;
- Generation of pressure within the waste mass resulting from the phase change of liquid entrained in the waste mass to vapor phase and resulting settlement;
- Increased gas capture complexity due to the pressure increases at depth that release upward within the waste mass due to the increasing density of the waste with depth;
- Heating of waste which results in a steam/water vapor front moving out, up, and away from the SSE, which then condenses in the cooler surrounding waste mass and gas extraction wells resulting in higher localized leachate generation;

- Leachate characteristic changes including elevated constituents such as biological oxygen demand (BOD), volatile organic compounds, and dissolved and suspended solids that result from liberation of constituents from the as-received waste material and from the thermal degradation of biological material;

- Greater than normal settlement at the location of and/or adjacent to reacting waste mass resulting from the significantly reduced volume of waste mass; and

- Soot/tar-like materials that accumulate on Gas Collection and Control Systems (GCCS) components (flame arrestors, KOP, demister pads, well pumps, and small diameter hoses and lines).

Once waste temperatures begin to rise and are sustained within a landfill, the heating "front" may move further into the landfill (Ohio EPA, 2011). Subsurface smoldering events caused by reactions within a landfill begin at a point of origin, and then spread slowly into adjacent areas until conditions cease to be favorable for the SSE to continue (Bridgeton Landfill, LLC, 2013a). Factors affecting propagation include oxygen (air) intrusion, moisture, waste type/size, and void space (Ohio EPA, 2011).

## 3. ROD-SELECTED REMEDY

EPA selected a containment remedy for OU-1 that would protect human health and the environment by providing source control and institutional controls for the landfilled waste materials. A description of and reasons for selection of this remedy are presented in EPA's ROD for OU-1 (EPA, 2008). The source control and institutional control methods prevent human receptors from contacting the waste material. The source control method mitigates contaminant migration to air and restricts infiltration of precipitation into the landfill, which contributes to the protection of groundwater quality.

The components of the ROD-selected remedy include the following:

1. Install landfill cover meeting the Missouri closure and post-closure care requirements for sanitary landfills, including enhancements consistent with the standards for uranium mill tailing sites (i.e., armoring layer and radon barrier). The engineered landfill cover would consist of the following layers (from top to bottom):

    - A one-foot thick layer of soil capable of sustaining vegetative growth;

    - A two-foot thick infiltration layer of compacted USCS CL, CH, ML, MH, or SC soil-type with a coefficient of permeability of $1 \times 10^{-5}$ cm/sec or less; and

    - A two foot thick bio-intrusion/marker layer consisting of well-graded rock or concrete/asphaltic concrete rubble.

2. Consolidation of radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;

3. Apply groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;

4. Surface water runoff control;

5. Gas monitoring and control including radon and decomposition gas as necessary;

6. Institutional controls to prevent land and resource uses that are inconsistent with a closed sanitary landfill site containing long-lived radionuclides; and

7. Long-term surveillance and maintenance of the remedy.

The description and basis for the selected remedy was documented in the ROD.

Performance standards for each of the remedy components are specified in the ROD. As a result of subsequent discussions between EPA Region 7 and EPA's Office of Superfund Remediation and Technology Innovation (OSRTI), the following additional performance standards were identified for the ROD-selected remedy:

- The proposed cap should meet Uranium Mill Tailing Radiation Control Act (UMTRCA) guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions.

- Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations.

- Groundwater monitoring should be implemented at the waste management unit boundary and also at off-site locations. The groundwater monitoring program needs to be designed so that it can be determined whether contaminants from the landfill have migrated across the waste management unit boundary in concentrations that exceed drinking water Maximum Contaminant Levels (MCLs). The groundwater monitoring program needs to measure for both contaminants that have historically been detected in concentrations above MCLs (e.g., benzene, chlorobenzene, dissolved lead, total lead, dissolved arsenic, total arsenic, dissolved radium and total radium), and broader indicators of contamination (e.g., redox potential, alkalinity, carbonates, pH and sulfates/sulfides).

- Flood control measures at the site should meet or exceed design standards for a 500-year storm event under the assumption that the existing Earth City levee system is breached.

Evaluation of how the ROD-selected remedy addresses these additional performance standards and a refined description and evaluation of the containment remedy selected by EPA and documented in the ROD was presented in the Supplemental Feasibility Study (SFS) (EMSI, 2011).

## 4. POTENTIAL ARARS RELATIVE TO AN SSE

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) requires that remedial actions be analyzed for compliance with applicable or relevant and appropriate requirements (ARARs) of other environmental laws and regulations. ARARs are divided into three categories:

- Chemical-specific ARARs;
- Location-specific ARARs; and
- Action-specific ARARs.

Descriptions of ARARs, the criteria used to identify whether a requirement is potentially applicable or relevant and appropriate, and identification of potential ARARs for OU-1 are provided in the FS report (EMSI, 2006). Additional evaluations of ARARs as they relate to the “complete rad removal” alternatives are provided in the SFS report (EMSI, 2011).

These prior evaluations identified the various potential ARARs including chemical-specific ARARs associated with the chemicals observed to be present at the site, the location-specific ARARs (e.g., requirements associated with the proximity of the site to Lambert-St. Louis International Airport and to the Missouri River), and action-specific ARARs associated with the presence of radionuclides and a municipal solid waste (MSW) landfill at the site. No additional potential ARARs associated with the potential occurrence of an SSE in OU-1 Areas 1 or 2 or possible interactions between an SSE and the radiologically-impacted materials were identified during this current evaluation. The previously identified ARARs describe the requirements associated with the design and maintenance of a landfill cover, including installation of an engineered cover over the RIM, landfill gas management, odor control, and other aspects of the engineering controls for the site.

## 5. POTENTIAL IMPACTS OF AN SSE ON THE RIM

Based on a review of published literature and evaluations performed relative to the SSE in the South Quarry Landfill (see prior discussions in Section 2), the impacts common to SSEs that could possibly result from an SSE at West Lake OU-1 could include the following:

- Increased temperatures in the waste mass, landfill gas and possibly leachate;

- Generation of increased vapor (gas) pressure within the waste mass resulting from the phase change of liquid entrained in the waste mass to the vapor phase;

- Changes in landfill gas production and quality;

- Changes in leachate and condensate production and quality;

- Increased emissions of odors, smoke or steam;

- Elevated levels of carbon monoxide, hydrogen, carbon dioxide, and volatile organics;

- Reduction in the volume of the waste mass from pyrolysis of the waste resulting in greater than normal settlement over and adjacent to the reacting waste mass;

- Damage to landfill infrastructure elements, after and to the extent they are installed;

- Slope failure; and

- Groundwater and surface water contamination.

Of these possible impacts, this evaluation will consider the physical and chemical conditions of the RIM at West Lake in order to assess what possible impacts could result in a potential release, emission or migration of radionuclides contained within the RIM. Based upon this, the possible impacts to be evaluated include:

1. Combustion;

2. Increased subsurface temperature;

3. Waste consolidation and pore space reduction; and

4. Vaporization of entrained moisture resulting in potential increases in radon emissions.

As discussed below, any effect of these possible impacts on radon release are expected to be limited because the rate of radon generation and emanation would remain the same – temperature does not change the radium decay rate which produces radon gas. While the impacts might increase the rate at which radon is released from the ground, these effects are expected to be localized given that the heat and steam fronts associated with an SSE event would be localized to the perimeter of the SSE and would stop when the SSE reaches the waste mass boundary. These impacts would also be temporary since they would stop when the SSE ends.

Other impacts identified above, such as increased odors, are associated solely with solid wastes and have no effect on the RIM in West Lake Areas 1 and 2. Some of the other impacts identified above, although not expected to directly affect the RIM, could affect the performance of one or more of the ROD-remedy components and are discussed in the next section of this report.

None of these possible impacts would affect the rate of radon generation (creation of radon from radium decay). However,, some of the impacts could affect the rate of radon emanation (the release of radon from the mineral grain), or the rate of radon exhalation (the release of radon at the ground surface).

## 5.1 Combustion

As discussed in Section 2, subsurface heating events at landfills typically do not include flaming combustion but rather persist at the smoldering stage of combustion. These fires are more likely to burn slowly without visible flame or large quantities of smoke (Thalhamer, 2013). Flames or smoke do not occur with smoldering events unless the subsurface fire is excavated or otherwise exposed to the atmosphere (Thalhamer, 2013). Therefore, the release of radionuclides through gaseous emissions by flaming would not occur with a subsurface smoldering event.

Also, as discussed in Section 2, a combustible mixture of methane and oxygen requires a very high temperature to ignite (>500 °C / 932 °F) (Moqbel et al., 2010). Temperatures typically associated with subsurface smoldering events are reported to range from 212 or 250 °F (100 or 121 °C) up to 450 °F (232 °C) (Thalhamer, 2013). Therefore, although temperatures could reach the levels where smoldering combustion of paper and other materials could occur, the temperatures that are expected to occur in conjunction with an SSE should not reach the levels necessary for ignition and explosion of methane within the landfill mass. Furthermore, methane production often decreases during a subsurface heating event because methane-producing microorganisms are inhibited by high temperatures (Ohio EPA, 2011). Methane generation in waste is also dependent upon the age of the waste, and the wastes at OU-1 are at least 30 years old or older. Finally, methane production also decreases significantly when temperatures are elevated above 160 °F / 71 °C (Bridgeton Landfill, LLC, 2013a). Consequently, the conditions necessary for a methane explosion and a corresponding explosive release of radionuclides from Area 1 or 2 at the landfill will not occur.

## 5.2 Increase in Subsurface Temperature

As set forth above, temperatures typically associated with subsurface smoldering events are reported to range from 212 or 250 °F up to 450 °F (100 or 121 to 232 °C) (Thalhamer, 2013). In the South Quarry Landfill, downhole temperatures near the SSE range from approximately 175 to 185 °F (79 to 85 °C). Monitoring locations within the waste mass in the area of the SSE have measured temperatures slightly above 300 °F / 149 °C and another displayed a temperature of approximately 225 °F / 107 °C (Bridgeton Sanitary Landfill, 2013d). At the Hunter's Point Landfill in California, a vent gas temperature of 480 °F / 249 °C associated with an SSE was reported (Thalhamer, 2013). The RIM at the site consists of leached barium sulfate residue mixed with soil. The melting point of barite (barium sulfate) is reported to be greater than 1,300

°C / 2,372 °F (Chem Alert 2, 2007) or 1,580 °C / 2,875 °F (Chemnet, 2013, and Chemicalland, 2013). Therefore, the heat that has been observed and/or could be generated within the landfill materials within West Lake Areas 1 and 2 could not approach the amount of heat necessary to melt or otherwise disrupt the stability of the RIM.

Additionally, the dissipation of heat through the landfill surface would greatly limit the potential for a buildup of heat in the uppermost portion of the landfill mass. Because of the relatively low thickness of the surrounding and overlying waste materials in West Lake Areas 1 and 2 compared to the deep waste materials surrounding and overlying the materials fueling the SSE at the South Quarry Landfill (Attachment 1), the waste environment in West Lake Areas 1 and 2 would not create the same insulation effect as is created in the South Quarry Landfill, and any generated heat in West Lake Areas 1 and 2 would dissipate into the surrounding overburden and native soil and rock. In addition, the relatively low thickness of the surrounding and overlying waste materials in West Lake Areas 1 and 2, as compared to the substantial depth of the Bridgeton quarry-fill environment, results in substantially lower loading (pressure) on the waste materials and therefore less consolidation and lower waste densities than likely occur in the Bridgeton South Quarry Landfill, where the waste column is 250 feet or more deep (Attachment 1). DeHavilland (2011) has theorized that the weight of the disposed material and the resulting overburden pressure may be a contributing factor to the buildup of excess heat and possible ignition of landfill materials. Consequently, the lower overall thickness of the waste deposits in West Lake Area 1 or 2 should result in lower amounts of pressure, lower heat accumulation, and therefore lower temperature increases than those observed in the substantially thicker and consequently denser refuse deposits present in the Bridgeton South Quarry Landfill.

In addition, any increase in temperature would have no effect on radioactive decay of the RIM in Areas 1 and 2. Radioactive decay is a function of time and the half-lives of the various radionuclides. Radioactive decay is independent of temperature or pressure conditions (MIT, 2009), and therefore increases in temperature or pressure will not increase or otherwise affect the rates of radioactive decay within the RIM. Therefore, evaluation of the possible effects of an SSE on the RIM will primarily focus on potential changes that could affect the rates of radon release.

Intuitively, one might posit that radon flux (migration) and resultant radon exhalation would increase with increasing temperature because diffusion is directly proportional to temperature; however, there are conflicting reports about the degree to which temperature affects radon exhalation (ORISE, 2011). Increasing temperatures can affect the amount of moisture within the waste and soil and consequently affect the rates of radon migration and radon exhalation. These effects are discussed further below.

## 5.3 Waste consolidation and pore space reduction

Pyrolysis of the waste in conjunction with an SSE produces a reduction in the waste mass, a reduction in total void spaces (or pore spaces), and potentially a reduction in the porosity of the waste materials. Reducing the total void space and possibly the waste porosity should theoretically result in a reduction in the radon emanation rate (the rate at which radon is released from the RIM to the air and liquids within the pore spaces). Radon emanation rates are a function of pore size and overall porosity (Sun and Furbish, 1995). If the pore space is very small and the opposing surfaces are close, the radon might embed into an adjacent surface instead of staying in the water or air phase within the pore space (Sun and Furbish, 1995). The radon which attaches to a nearby solid is considered embedded (Sun and Furbish, 1995). Thus, only the radon within the pore space, that is therefore available for migration and subsequent release, is considered as emanated (Sun and Furbish, 1995). Therefore, a reduction in porosity would decrease the radon emanation rates (release from the mineral grain) and consequently result in a decrease in the radon exhalation rates (release from the ground surface).

## 5.4 Vaporization of Entrained Moisture

An increase in subsurface temperatures could result in vaporization of entrained moisture and subsequent reduction in the moisture content of the buried waste and soil. Reduction in waste/soil moisture can have several effects, some of which could result in a decrease in the amount of radon emanation (release of radon to the pore spaces) and some of which could result in an increase in radon exhalation (release of radon at the ground surface). Specifically, a reduction in waste/soil moisture could lead to a reduction in the rate of radon emanation (release of radon from the mineral grains). Conversely, vaporization of entrained moisture could release radon that is dissolved within the soil moisture resulting in a slight increase in radon mass within the landfill and a resultant temporary increase in the amount of radon available for exhalation (release at the ground surface). Vaporization of entrained moisture could also result in creation of a steam front that could result in localized increases in vapor pressure which could also increase radon migration and emission (exhalation) rates. In addition, reduction in waste/soil moisture could also lead to increased soil permeability resulting in increased radon migration and exhalation (radon emission at the ground surface). Each of these effects is discussed further below.

### 5.4.1 Effect of moisture vaporization on radon emanation

Radon is generated by the decay of radium within a mineral grain. In order for radon to be released, it must move from within the mineral grain to the outside of the solid mineral grain (radon emanation) where it has a potential for migration and release from the ground (Al-Ahmady 1995). The transition process controlling this transfer from inside to outside the solid mineral grain is called radon emanation (Salimitari, et al., 1996). For most soils containing radium constituents, only 10-50 percent of the radon generated within the mineral grain actually is released (emanates) from the mineral grain and enters the pore volume of the soil (USDOI, 1992). There is at least one study indicating that radon emanation rates from radium-bearing rocks decrease with increasing temperature (Garver and Baskaran, 2004).

Studies (Rogers, et al., 1984, Sun and Furbish, 1995) have indicated that the presence of moisture within the pore spaces increases radon emanation because radon emanation rates are greater for liquid than for air. Among the factors that influence radon emanation, soil moisture content has been demonstrated to have a significant impact (Strong & Levins 1982). Fluid-filled soil pores contain most of the soil moisture (Salimitari, et al., 1996). When the content of water in the pore space increases, the direct radon emanation coefficient component is increased, because a greater fraction of the recoil radon atoms are trapped in the pore space (Salimitari, et al., 1996). Trapping of recoiled radon atoms generated from radioactive decay of radium in the pore space is profoundly reduced when capillary water surrounding solid mineral grain is reduced or eliminated (Salimitari, et al., 1996). This means that radon moves more easily from the grain into surrounding water, but when surrounding water is unavailable there is less tendency for the radon to move from the mineral grain into the pore space (emanate). Therefore, a reduction in soil moisture content as a result of vaporization of entrained moisture could result in a reduction in radon emanation and an attendant reduction in the amount of radon available for exhalation (release from ground surface, discussed below).

### 5.4.2 Release of radon dissolved in soil moisture

Vaporization of entrained moisture could potentially result in a slight, temporary increase in radon emission (exhalation) due to the release of radon dissolved in the entrained moisture (i.e. radon that had been emanated from the mineral grain into surrounding moisture). Although radon is a gas, it is slightly soluble in water. Vaporization of entrained moisture could result in a temporary release of that portion of the radon that is dissolved within the entrained moisture.

Radon is subject to retrograde solubility: that is, the solubility decreases with increasing temperature. Therefore, an increase in temperature could result in an increased release of radon that is dissolved in moisture entrained in the RIM and waste, as opposed to radon entrained within the mineral grain itself. This effect could potentially result in a slight, temporary increase in radon emission (exhalation) at the ground surface due to the release of radon dissolved in entrained moisture.

The RIM and any entrained moisture that contains radon is in equilibrium with the air in the pore spaces in the RIM and adjacent refuse. Therefore, radon entrained in the soil moisture will naturally transfer to the gas phase within the pore spaces and consequently the mass (amount) of radon contained in the entrained moisture is expected to be small. Still, some very small fraction of the generated radon could be present in the entrained moisture. If an SSE were to occur, one of the effects would be for the advancing heat front to vaporize the entrained moisture (i.e., a steam front). Vaporization of the entrained moisture within the RIM would result in transfer of whatever radon was dissolved in this moisture from the liquid phase to the vapor phase.

Because the amount of entrained moisture is finite and the rate of radon generation is independent of the soil moisture content, any release of radon from entrained moisture would be a temporary effect. Therefore, vaporization of entrained moisture could potentially result in a slight, temporary increase in radon release at the surface in the immediate area of the increased heat front associated with an occurrence of an SSE in West Lake Area 1 or Area 2. This increase is expected to be small due to the small amount of radon that would be dissolved in the interstitial moisture. This effect will also be temporary due to the finite amount of moisture entrained within the RIM and associated refuse. This effect is also expected to be localized due to the localized nature of the heat front associated with an SSE.

### 5.4.3 Increase in vapor pressure

The presence of elevated temperatures resulting from an SSE can cause vaporization of moisture entrained within the landfill mass. In the vicinity of the heat front around an SSE, vaporization of the entrained moisture within the refuse and RIM could result in an increase in interstitial vapor pressure as a result of the conversion of the entrained moisture from liquid to vapor (i.e., a steam front). The waste which previously held moisture entrained in cellular structures, voids or other means of stable entrapment shrinks, making it smaller and more dense, and this reduction in the waste volume (and increase in the waste density) can result in increased liquid saturation levels within the remaining waste mass until such time as the free moisture either flows away or evaporates.

A SSE could also increase landfill gas generation from decomposition of the destroyed (pyrolyzed) waste volume by the SSE. Such an increase in landfill gas generation would be localized to the area of the SSE. An increase in landfill gas generation could result a temporary increase in radon migration to the surface due to the increase in landfill gas pressure gradients and landfill gas flux.

An increase in vapor pressure could potentially result in a slight, temporary increase in radon migration rates due to the increased interstitial vapor pressure gradients in the immediate area of the increased heat front associated with an occurrence of an SSE in West Lake Area 1 or Area 2. An increase in radon migration rates would decrease radon attenuation (reduction from natural radioactive decay of radon) because the radon vaporized within the steam would move more quickly through the subsurface. This would allow less time for natural degradation before reaching the surface and therefore could result in a temporary increase in radon exhalation (release at the surface). Such potential, temporary increases in radon migration and exhalation rates are expected to be localized due to the localized nature of the heat/steam fronts.

The possible effects that could result from vaporization of entrained moisture are expected to be temporary. Because the rate of radon generation is limited by the rate of radon decay, the total amount of radon generated will not increase. Therefore, the effect of increased vapor and landfill gas pressures and fluxes are expected to result in only a temporary, potential increase in radon release at the surface. These effects are also expected to be localized given that the heat and steam fronts associated with an SSE event would also be localized to the perimeter of the SSE. The short decay time for radon gas will result in a further limitation on the duration and extent of any effect since radon released from the site would be expected to decay within a limited time from release.

### 5.4.4 Increase in waste/soil permeability

Reduction in the moisture content of the refuse deposits and soil could result in a localized increase in waste/soil permeability. Any increase in subsurface permeability could potentially increase rate of radon migration through the refuse and soil because there is more space within the waste mass through which the radon can migrate towards the surface. An increase in radon migration rate would reduce the amount of time available for radon decay and therefore potentially could result in an increase in radon exhalation (release at the surface). An increase in the permeability of the soil cover over the waste deposits could result in a further increase in the radon exhalation rate (release at surface). Conversely, as previously discussed, pyrolosis of the waste materials produces a reduction in the waste mass and as a consequence, a reduction in the porosity (amount of void space) of the waste materials. A reduction in the porosity of the waste materials should result in a reduction in the permeability of the waste, thereby reducing radon migration rates.

In addition to vaporization of entrained moisture within or adjacent to the RIM, the advancing heat front could also vaporize entrained moisture within the refuse and associated soil located above and around the RIM. Because migration of radon in the subsurface is strongly affected by the degree of water saturation of the soil and refuse (Antonopoulos-Domis, et al., 2009, NRC, 1989, Papchristodoulou, et. al., 2007, Papchristodoulou, et. al., 2009, Rogers, et al., 1984, Rogers and Nielson, 1988), a decrease in entrained moisture could potentially result in a decrease in radon attenuation (reduction due to natural radioactive decay of radon) and consequent increase in radon exhalation rate (release at surface) if an SSE were to occur in West Lake Area 1 or 2.

Because radon generation is limited to the rate of radioactive decay, the total amount of radon generated will not increase; however, a reduction in the soil moisture content could reduce the amount of attenuation (decay) of the radon within the landfill mass before it reaches the landfill surface thereby resulting in a potential increase in radon exhalation (surface emission of radon). Such an increase is expected to be temporary, lasting only as long as the SSE heat front sustains vaporization of moisture entrained within the waste/soil materials. With cessation or lateral migration of an SSE heat front and subsequent infiltration of precipitation, the moisture content of the refuse/soil should increase, returning to near the levels that existed prior to passage of an SSE through a particular area.

## 6. POTENTIAL IMPACTS OF AN SSE ON THE ROD-SELECTED REMEDY

As noted above, there are numerous potential impacts which could result from the presence of a heating event. In addition to assessing the impact of a heating event on landfills in general and the RIM specifically, as discussed above, this evaluation also considered what impacts would be relevant to the components of the ROD-selected remedy. A potential SSE within West Lake Area 1 or 2 could result in three possible impacts to the components of the ROD-selected remedy. These include direct combustion of the engineered components, thermal damage to the engineered components, and differential settlement of the engineered components. However, as discussed below, it does not appear that any such impacts alter the effectiveness of the ROD-selected remedy and, specifically, any radon emissions.

## 6.1 Direct Combustion

The design of the ROD-selected remedy is based on use of natural materials (soil and rock) which are not subject to any type of combustion (either flaming or smoldering). Therefore the selected materials of the ROD-selected capping system would not be directly affected or damaged by the presence of either a smoldering or flaming fire within the landfill mass. As such, the performance of those components would not be adversely affected.

## 6.2 Thermal Impacts

In addition to vaporizing entrained moisture within the landfill mass, the increased temperature associated with an SSE has the potential to drive moisture out of the landfill cover materials. A reduction in the moisture content of the low permeability layer within the engineered landfill cover could increase the overall permeability of the cover system. Although no specific studies of the impacts of heat on low permeability soil layers within landfill covers systems have been found, studies of landfills with heat generating events have reported that the long-term efficiency of composite liners at the base of the landfills was imperiled by desiccation and subsequent cracking of the mineral liner (e.g., bentonite layer) below the geomembrane (Doll, 1997; and Southen and Rowe, 2011). Therefore, it is likely that the occurrence of elevated temperatures within the upper portions of a landfill could have a similar effect on the efficiency of low permeability layers composed of compacted soil, or composite layers consisting of a mineral (e.g., bentonite) layer.

Because the primary purpose of the low permeability layer is to reduce infiltration of precipitation into the landfill and to reduce radon release, an increase in the permeability of the landfill cover could result in an increase in leachate generation (due to infiltration) and radon exhalation rates (greater release at the surface due to reduced attenuation). Such impacts may be partially mitigated, and thus potentially of a temporary nature, because infiltrating precipitation would subsequently act to raise the moisture content of the low permeability layer. Depending upon the amount and nature of the clay content of the low permeability layer, some residual damage to the low permeability layer may occur. If the low permeability layer is primarily composed of silts or non-expansive clays, desiccation cracks could form in the cover and persist even if subsequent infiltration were to increase the moisture content of the low permeability layer. If the low permeability layer contains expansive clay, the re-wetting and resultant swelling of the clay minerals should act to seal such cracks.

At an extreme, the presence of elevated temperatures could damage or possibly destroy the vegetative cover over those portions of the landfill that are subject to an SSE. A reduction in moisture content of the vegetative layer could kill the vegetation. The purpose of the vegetative cover is to reduce potential infiltration of precipitation and to protect the underlying low permeability layer from erosion or freeze-thaw damage. Because any potential damage to the vegetative cover can be easily identified through visual observation and repaired through re-seeding/revegetation efforts, such an impact is expected to be only temporary. Ongoing routine inspection and maintenance of the landfill cover, as required by the ROD-selected remedy, would result in the identification and repair of such a condition.

The ROD-selected remedy calls for inclusion of a minimum two-foot thick rock layer at the base of the engineered landfill cover immediately over the existing landfill surface.
The primary purposes of this rock layer are to serve as a marker layer, to provide protection in the event that significant erosion were to occur to the landfill cover, and to reduce the rate of radon migration and thereby contribute to radon attenuation. The rock layer will not be adversely impacted by increased temperature. Additionally, this rock layer will provide insulation and isolation between any potential heating that may occur within the underlying waste mass and the overlying low permeability layer of the engineered landfill cover. Therefore, the current conceptual design of the ROD-selected remedy includes components (included for other purposes) that would also serve to reduce potential thermal impacts to the engineered landfill cover if an SSE were to occur in West Lake Area 1 or 2.

As such, the design and required maintenance of the ROD-selected remedy are sufficient to mitigate any potential thermal impacts and permit the ROD-selected remedy to continue to function as expected.

### 6.3 Differential Settlement

The most likely and most significant impact of a potential SSE on the ROD-selected remedy components would be the effects of SSE-driven waste consolidation and the resultant differential settlement of the engineered landfill cover system. If the reduction in the volume of waste materials were significant, it could lead to settlement of the overlying waste materials. Consolidation and settlement of the waste materials could lead to subsidence and differential settlement of the engineered landfill cover. Differential settlement of the engineered landfill cover would likely result in damage to the cover system which could negatively affect the performance of the landfill cover through desiccation, creation of cracks, or in the extreme, complete disruption resulting in offsets in the cover system layers. Such impacts could result in increased radon release at the surface, and increased precipitation infiltration into the underlying waste mass.

Any occurrences of differential settlement of the engineered cover would be readily identifiable by visual inspection of the landfill surface because such disruptions would be manifested at the ground surface in the form of depressions, cracks, or stressed or dead vegetation. Ongoing routine inspection and maintenance of the landfill cover, as required by the ROD-selected remedy, would result in identification and repair of such a condition. Consequently, the design and required maintenance of the ROD-selected remedy are sufficient to mitigate any potential negative effects of differential settlement and permit the ROD-selected remedy to continue to function as expected.

## 7. CONCLUSIONS

In the unlikely event of an SSE within Areas 1 or 2 of the West Lake Landfill OU-1, the heat generated by this theoretical event would not combust, melt or alter the stability of the RIM. Further, an SSE would not increase the production of radon, because the rate of radon generation within the waste is a constant based on the amount of source material and the rate of radioactive decay. An SSE might affect the rate of radon exhalation (the release of radon at the ground surface), because the exhalation of radon is a function of the migration of radon through the surrounding waste materials and engineered landfill cover over the relatively short time frame between radon generation and decay.

An occurrence of an SSE could potentially result in a temporary, localized increase in radon exhalation (release at the surface of the landfill cover), but would not result in any long-term increases in radon emissions from the landfill. Further, any such temporary, localized increases in radon release would be mitigated by the ROD-selected remedy.

As detailed above, conditions in the subsurface are not anticipated to have any substantial or lasting impacts on the conditions or performance of the engineered landfill cover near the ground surface. Engineered components of the ROD-selected remedy consist of rock and soil, which do not burn and are not subject to reaction or oxidation. Therefore, they would not be affected by an SSE, and the ROD-selected remedy would continue to function as a barrier to both infiltration of precipitation and release of radon gas to the surface.

Furthermore, the ROD-selected remedy directs ongoing monitoring, maintenance and use controls that would mitigate any impact from any short term increase in the rate of radon release.

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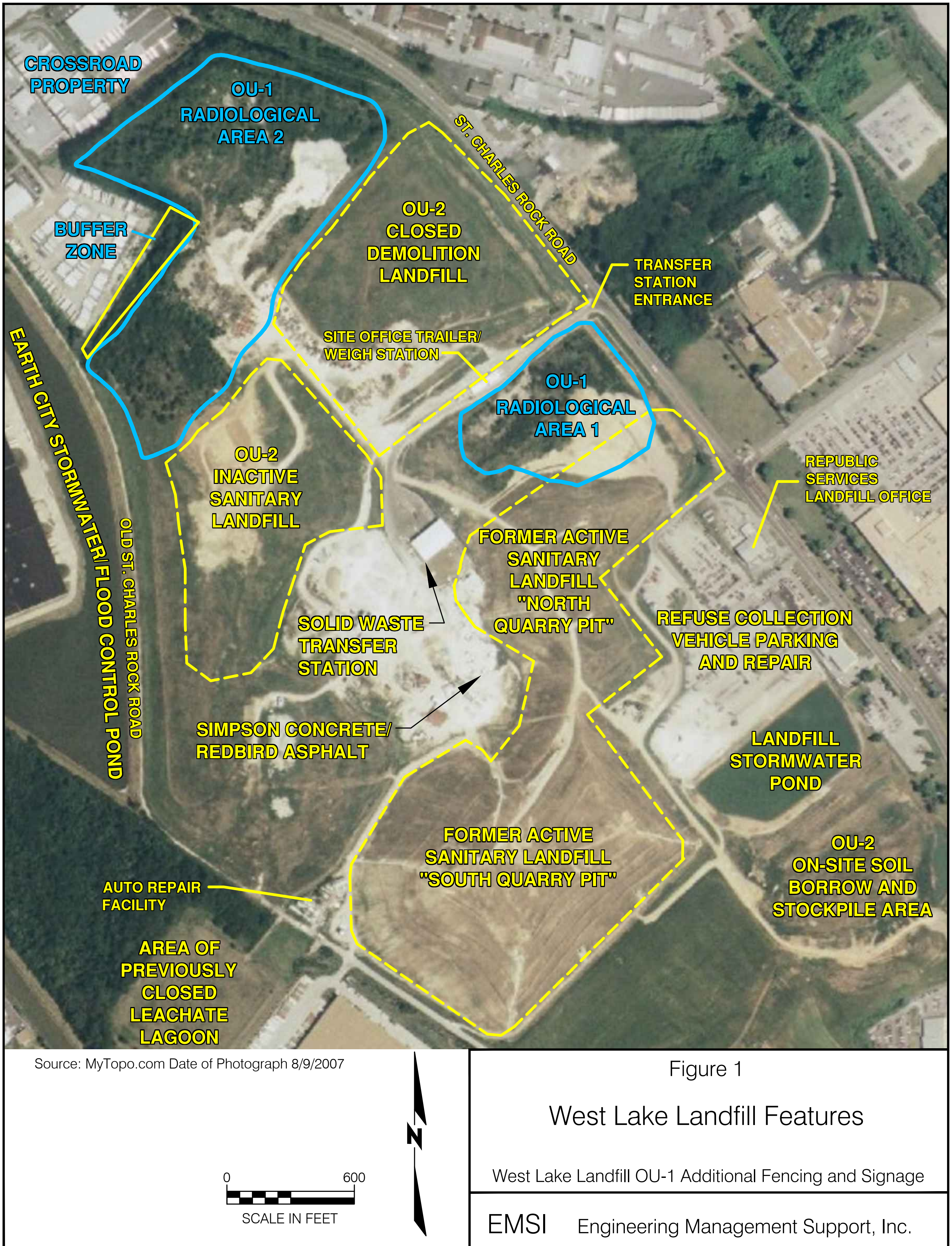
# FIGURE




Source: MyTopo.com Date of Photograph 8/9/2007

Figure 1

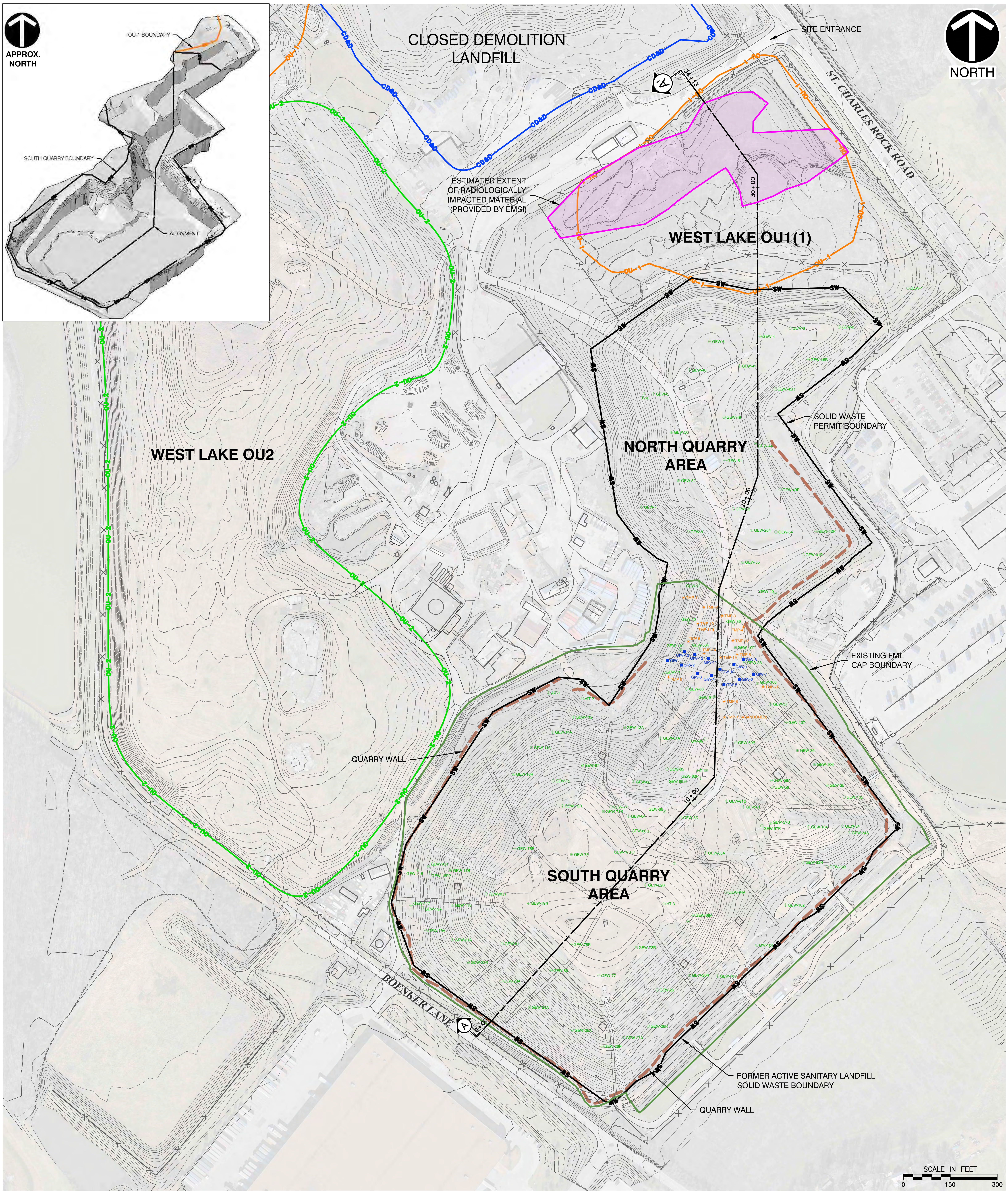
West Lake Landfill Features

West Lake Landfill OU-1 Additional Fencing and Signage

EMSI Engineering Management Support, Inc.

M:\clients\EMSI\westlake\2013\Fencing\WL-Fig-1-Site Features.dwg plotted: 05/15/2013

# ATTACHMENT

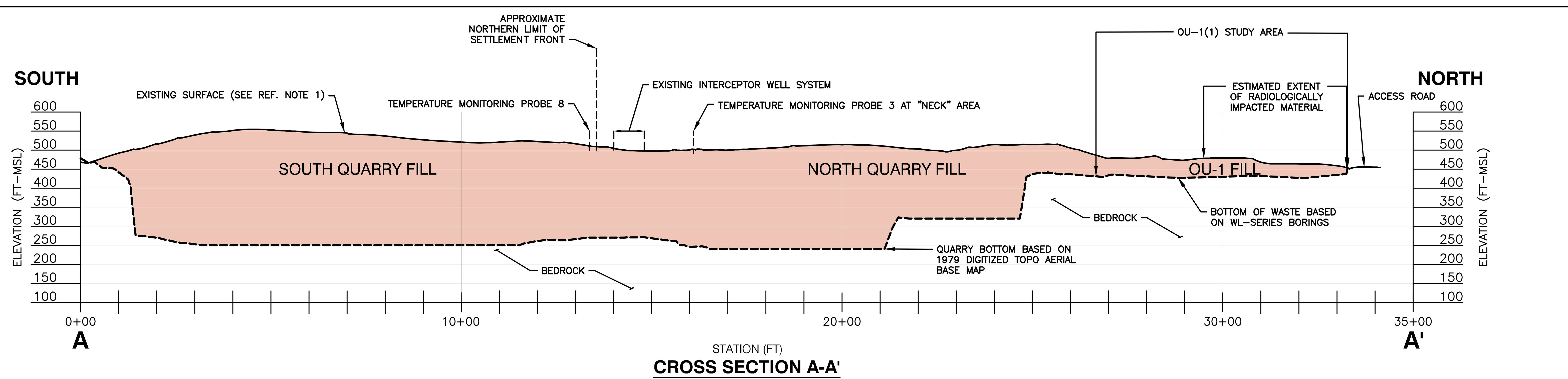



## LEGEND

| | |
|---|---|
| SW | EXISTING SOLID WASTE PERMIT BOUNDARY |
| OU-1 | EXISTING OU1 STUDY AREA BOUNDARY |
| OU-2 | EXISTING OU2 BOUNDARY |
| CD&D | EXISTING CLOSED DEMOLITION BOUNDARY |
| | EXISTING QUARRY HIGHWALL |
| | EXISTING FML CAP BOUNDARY |
| GEW-81 | EXISTING LFG EXTRACTION WELL (GEW) |
| TMP-6 | EXISTING TEMPERATURE MONITORING PROBE (TMP) |
| GIW-10 | EXISTING GAS INTERCEPTOR WELL (GIW) |

## REFERENCE

1. TOPOGRAPHIC INFORMATION BASED UPON BRIDGETON LANDFILL–DTM.DWG PROVIDED BY COOPER AERIAL SURVEYS CO., DATED FEB. 2013. PRELIMINARY SURVEY INFORMATION OF WELLS AND PROBES PROVIDED BY WEAVER BOOS CONSULTANTS.
2. AERIAL IMAGERY PROVIDED BY EAST WEST GATEWAY COORDINATING COUNCIL OF MISSOURI AND ILLINOIS, COLLECTED IN LATE FEBRUARY AND EARLY MARCH OF 2012.




**CROSS SECTION A-A'**

SCALE IN FEET
0 200 400

# BRIDGETON LANDFILL - EXISTING CONDITIONS

| | | | |
|---|---|---|---|
| DRAWN BY: | MSP | CHECKED BY: | MRB |
| APPROVED BY: | DRAFT | FIGURE NO.: | 2 |
| DATE: | NOV. 2013 | DWG SCALE: | 1"=150' |
| PROJECT NO: | 131-178.0001 | | |